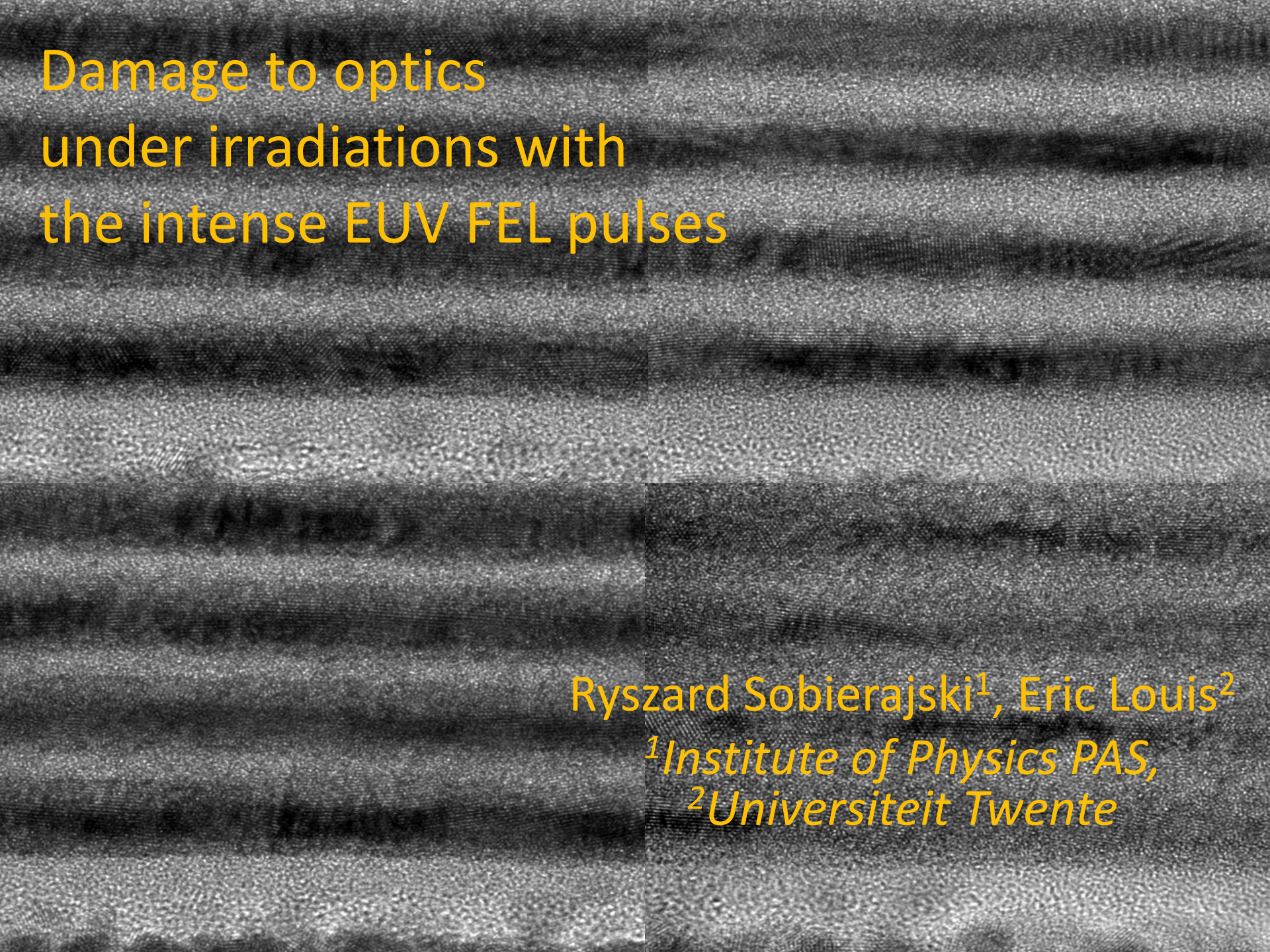
Damage to optics under irradiations with the intense EUV FEL pulses



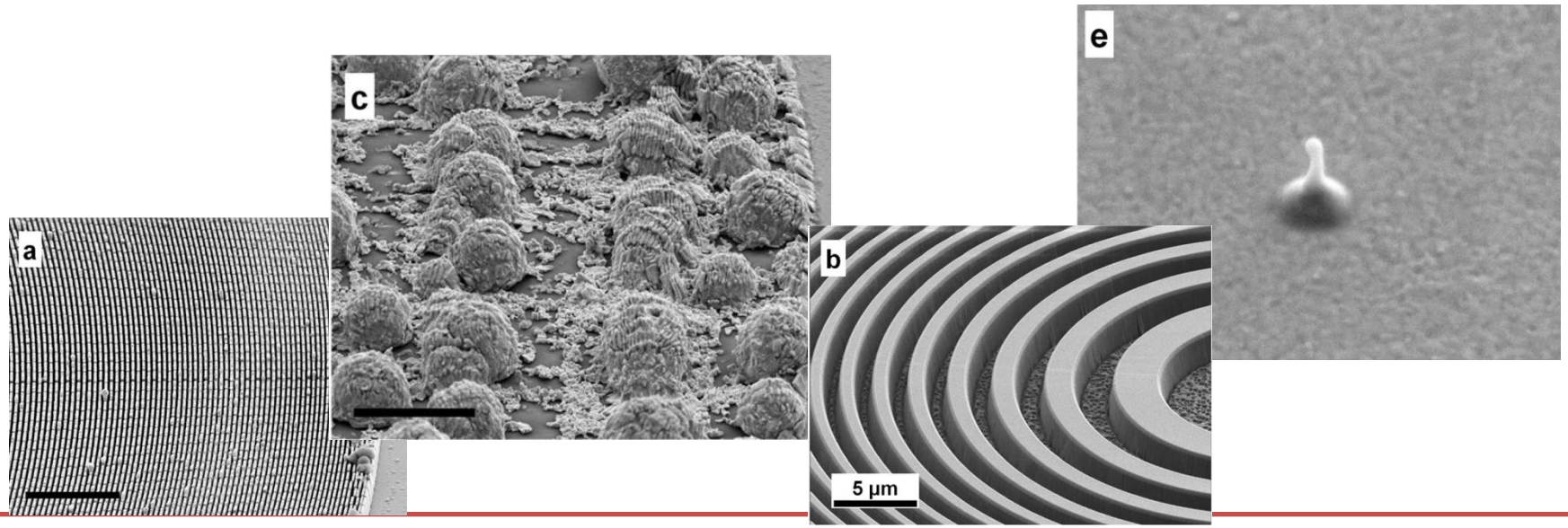
Ryszard Sobierajski[1], Eric Louis[2]

[1]Institute of Physics PAS,
[2]Universiteit Twente

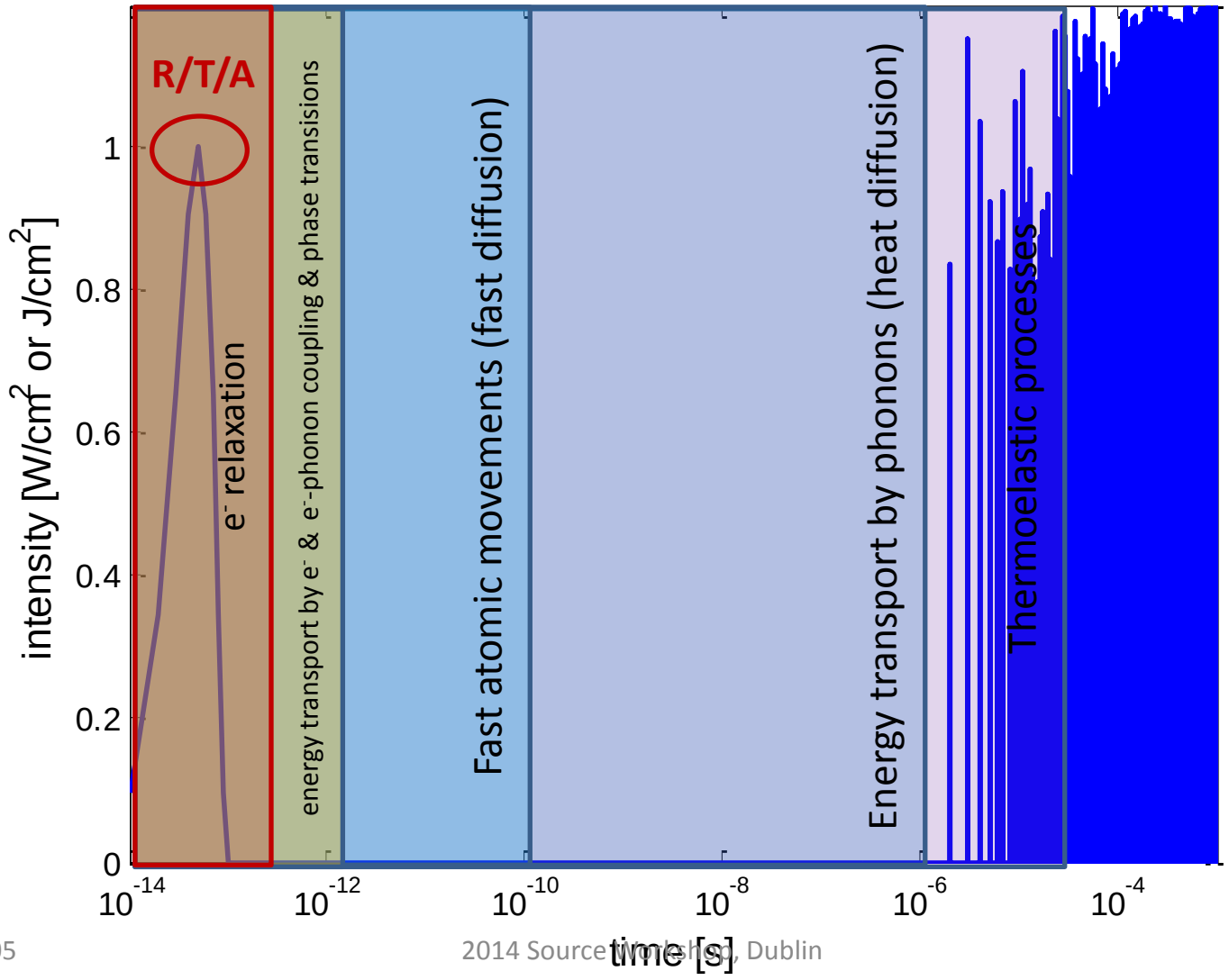
Damage to optics - motivation

Properties of the intense FEL beam create, apart new experimental opportunities, extreme demands to optical elements applied in the experimental equipment. Amongst the most serious issues is **radiation load** imposed on of **optics / detectors / samples.**

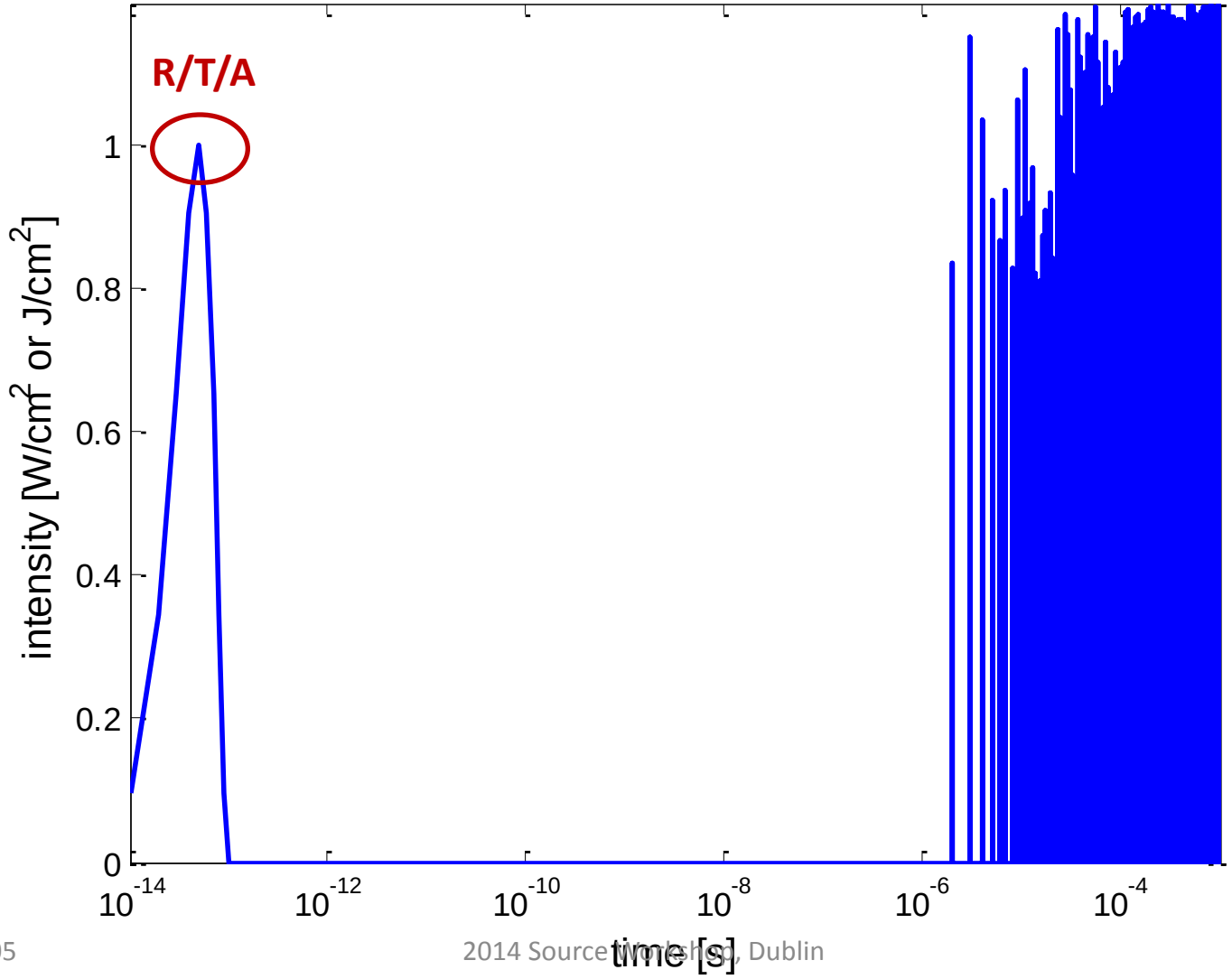
C. David et al. Scientific Reports Vol. **1**, (2011)



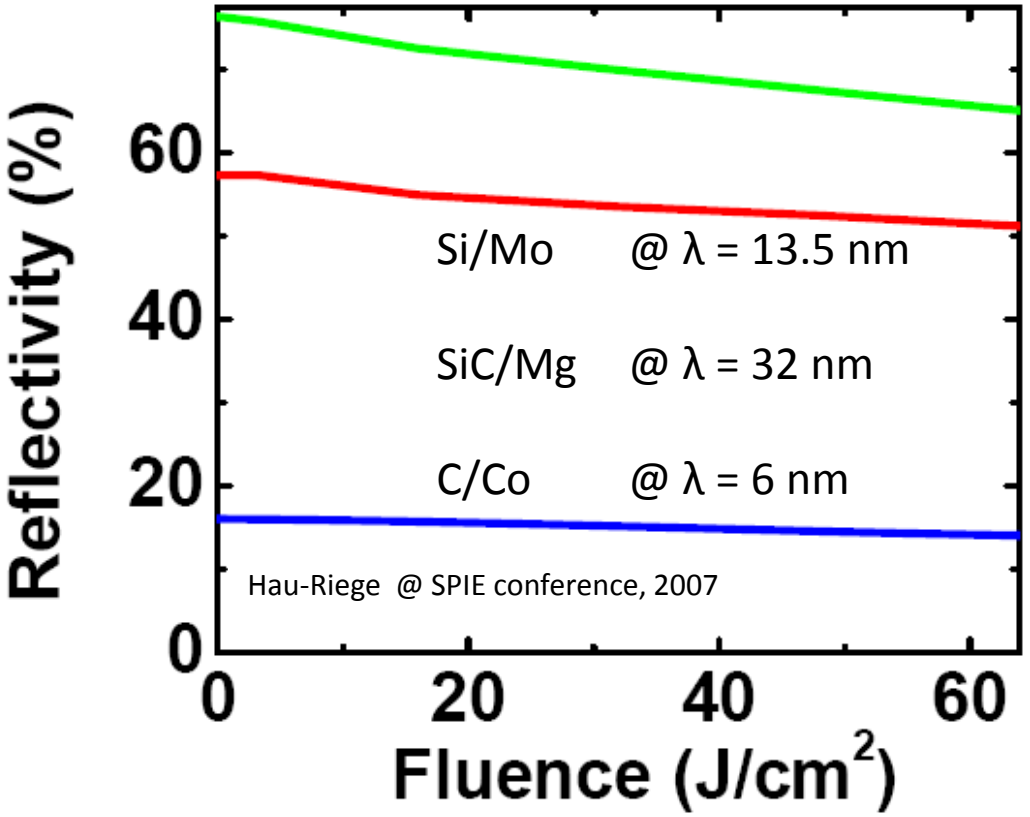
Characteristic times & processes



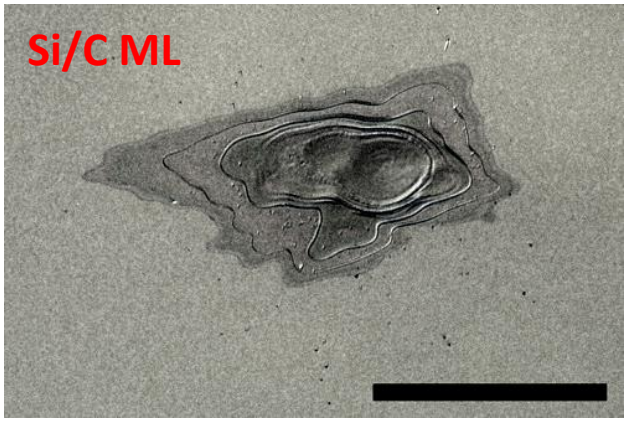
Characteristic times & processes

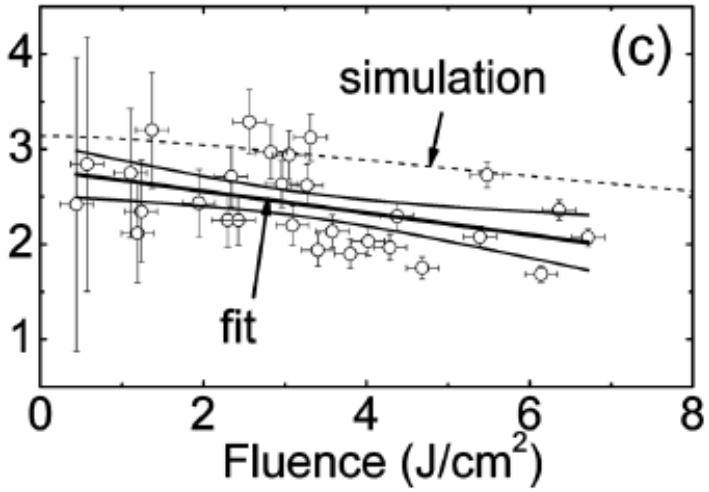


Intensity-dependent changes of optical properties – „single shot" optics

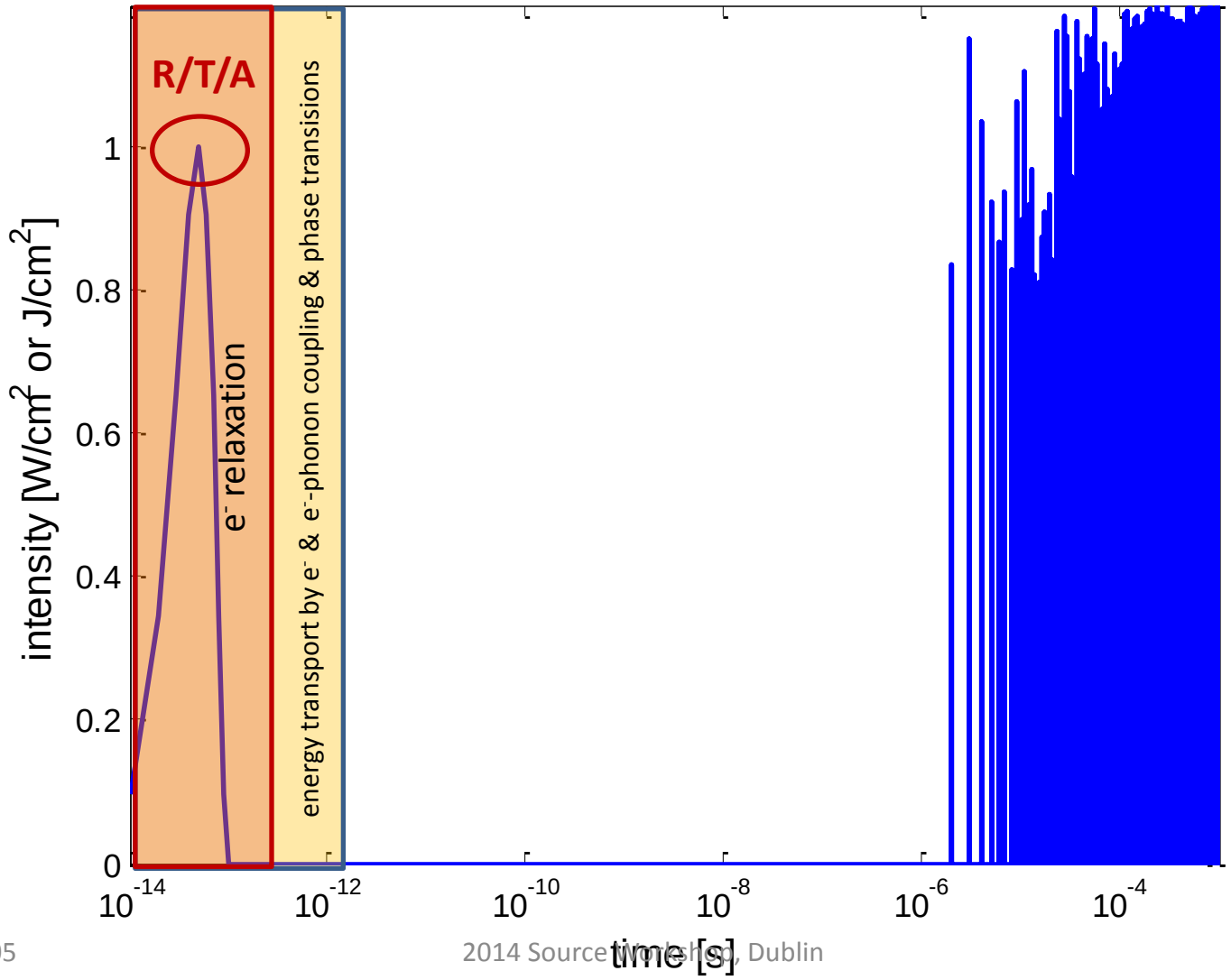


S.Hau-Riege, R.Sobierajski, PRL 98, 145502 (2007)



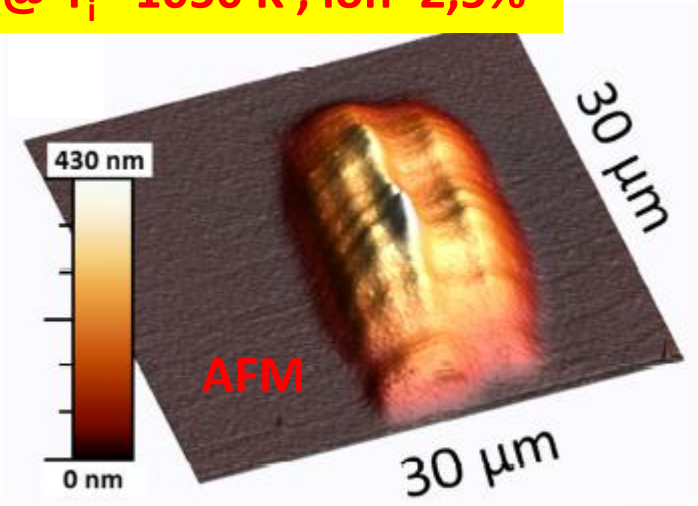


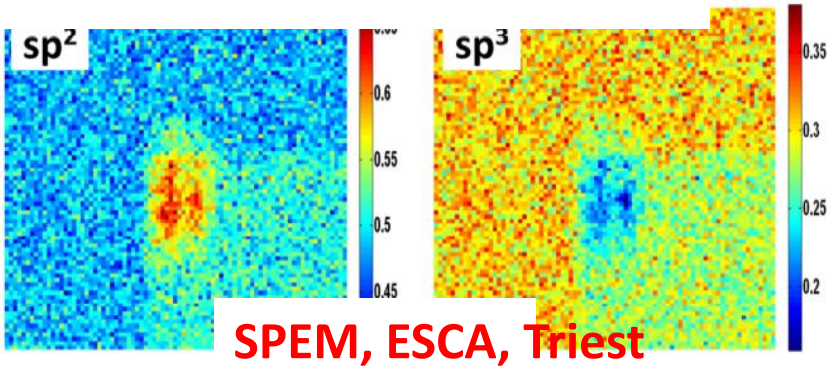
Characteristic times & processes



Phase transitions (s-s & s-l)

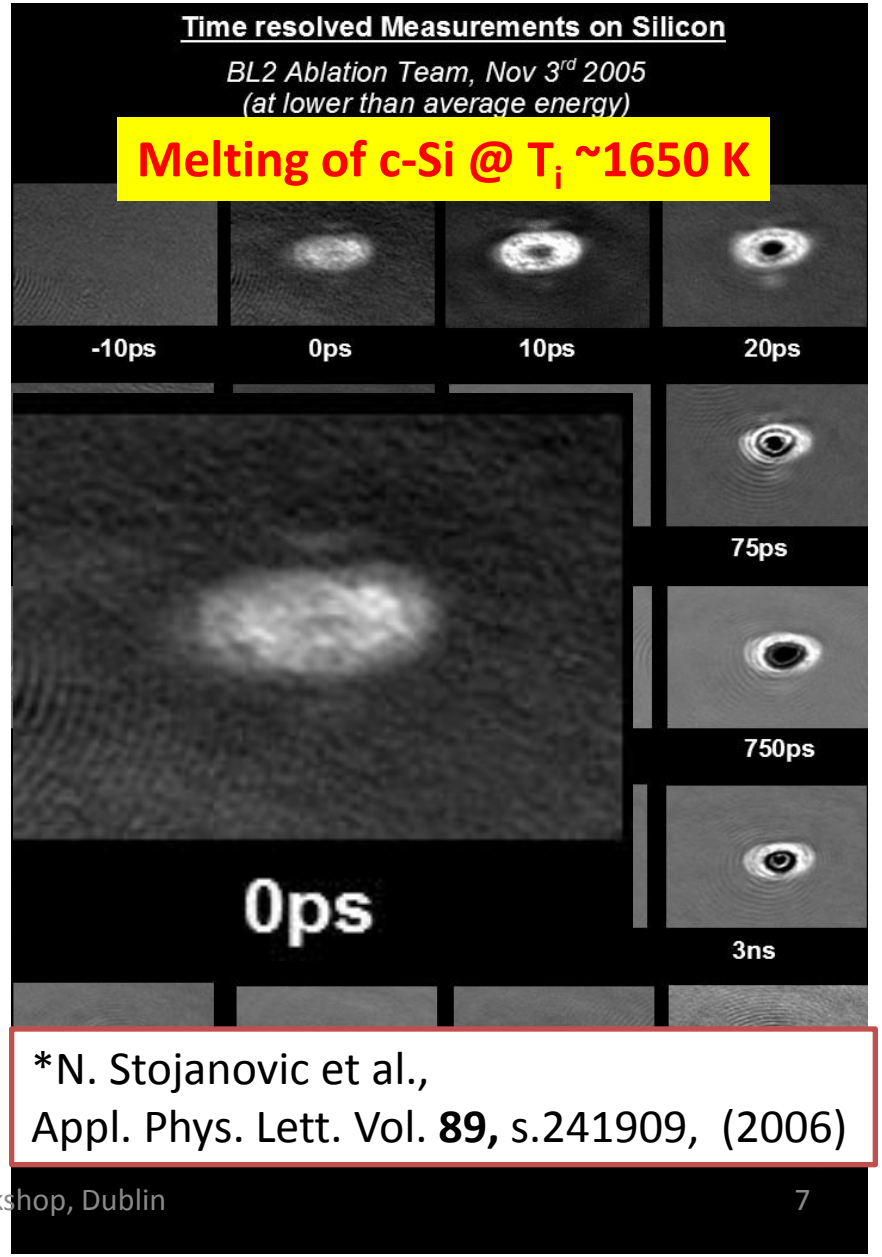
Graphitisation of a-C
@ T_i ~1050 K , ion~2,5%





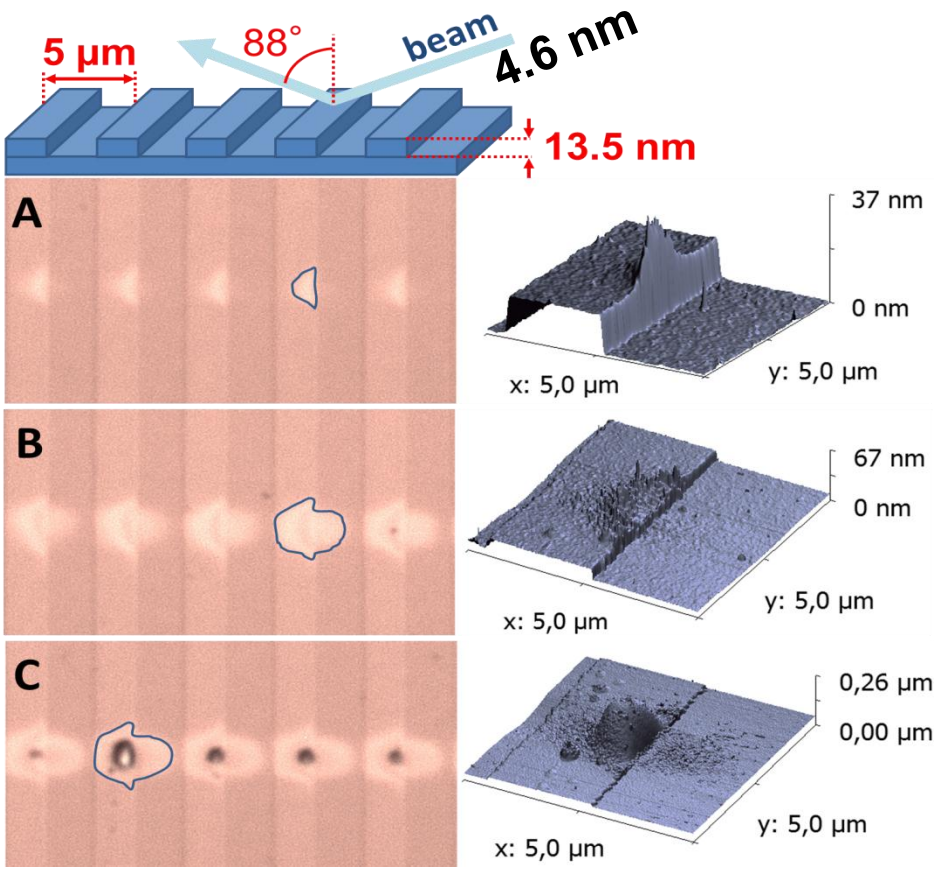
SPEM, ESCA, Triest

*J. Gaudin et al.,
Physical Review B 86 p.024103 (2012)

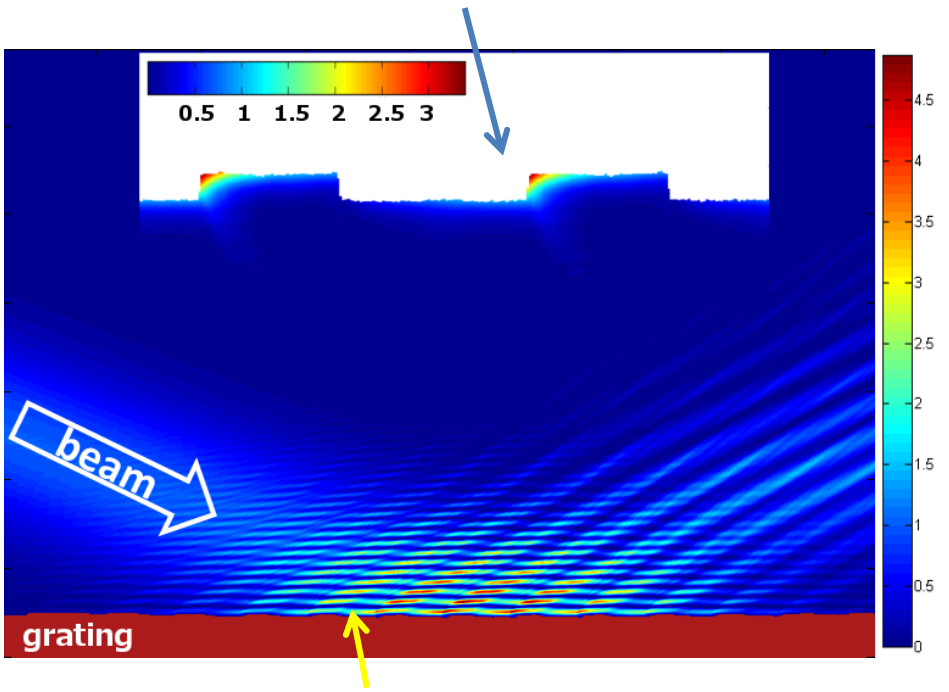


*N. Stojanovic et al.,
Appl. Phys. Lett. Vol. **89,** s.241909, (2006)

Thin (a-C) layers on gratings



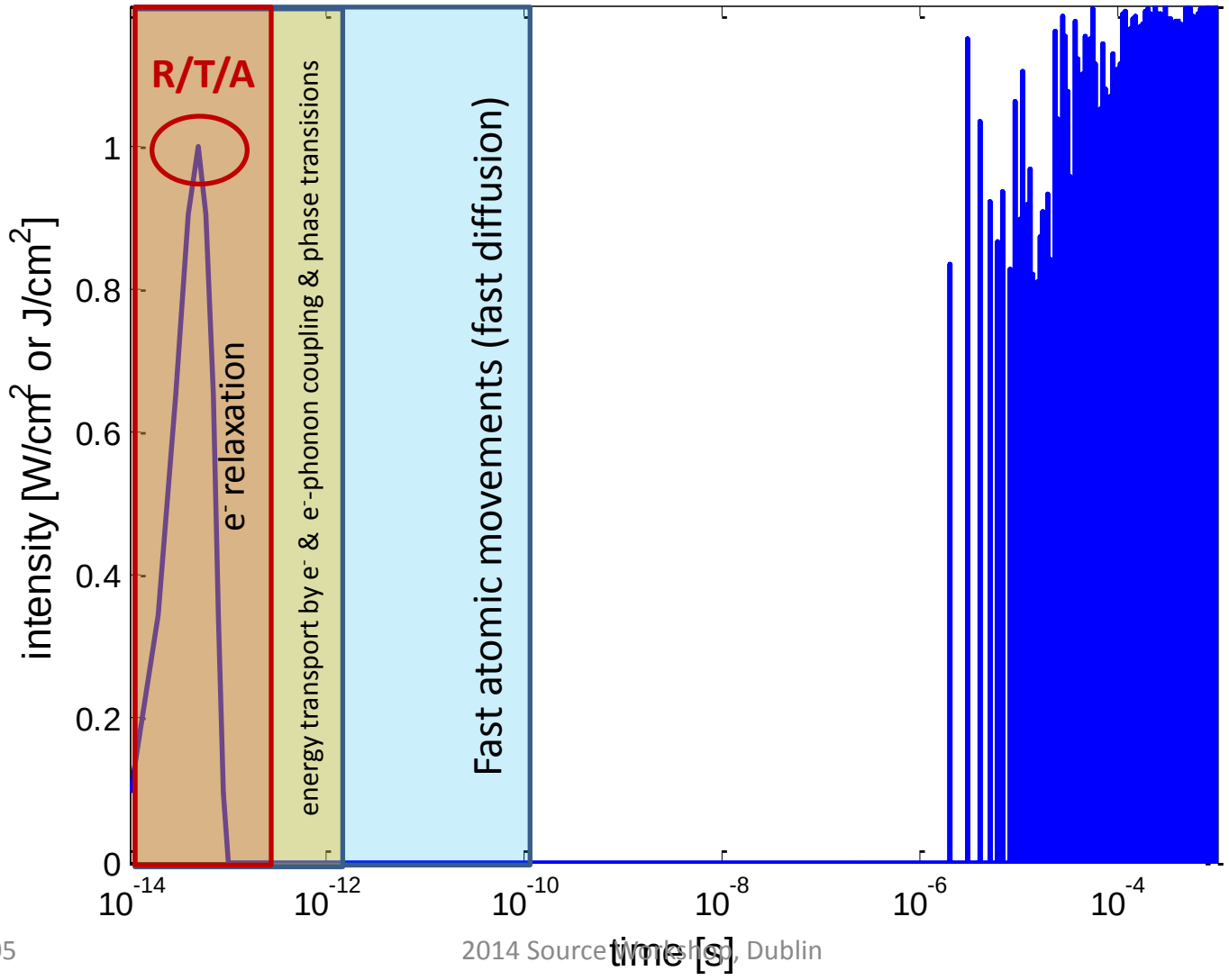
Energy distribution absorbed in the grating



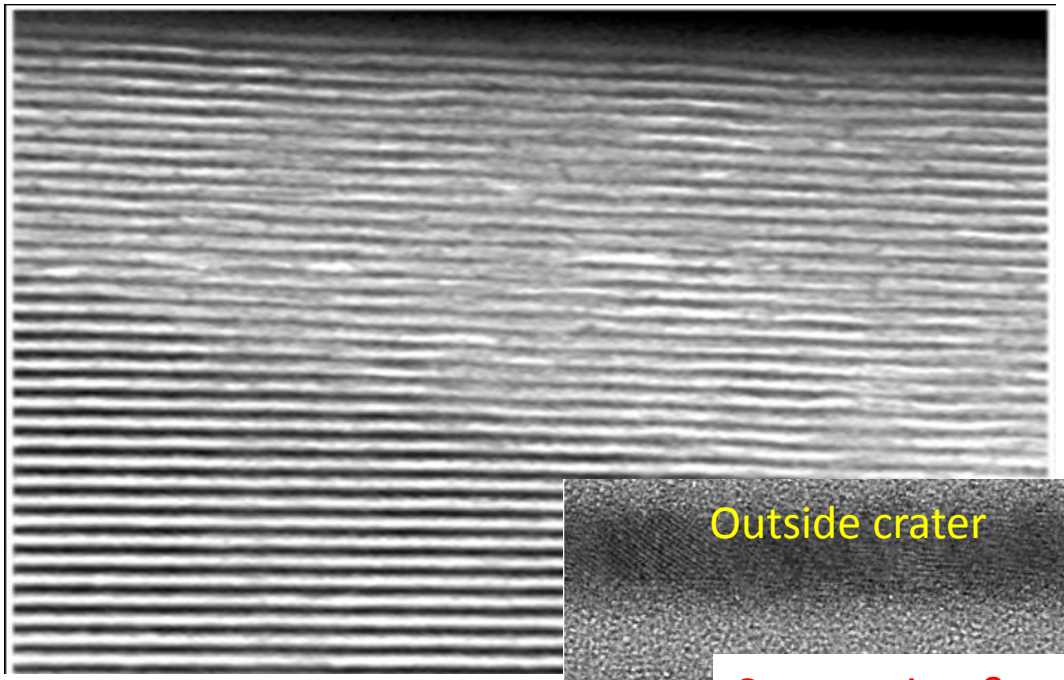
Simulations of the X-ray intensity distribution based on solution of the Helmholtz equation

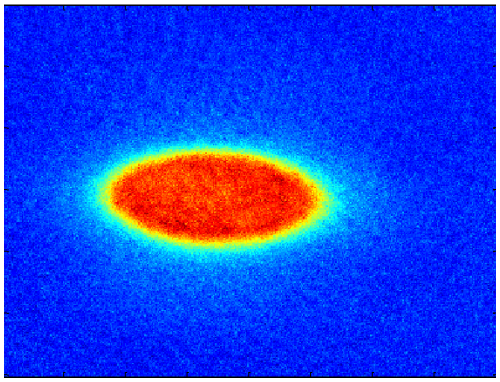
*J. Gaudin et al.,
Opt. Lett 37 p.2022 (2012)

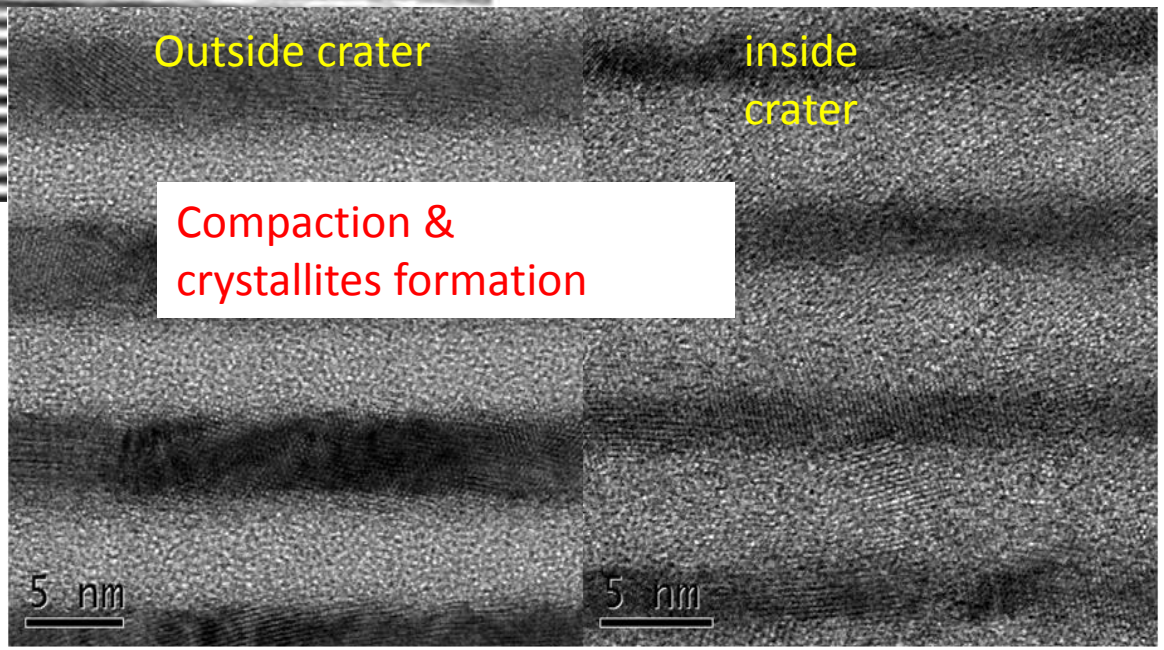
Characteristic times & processes



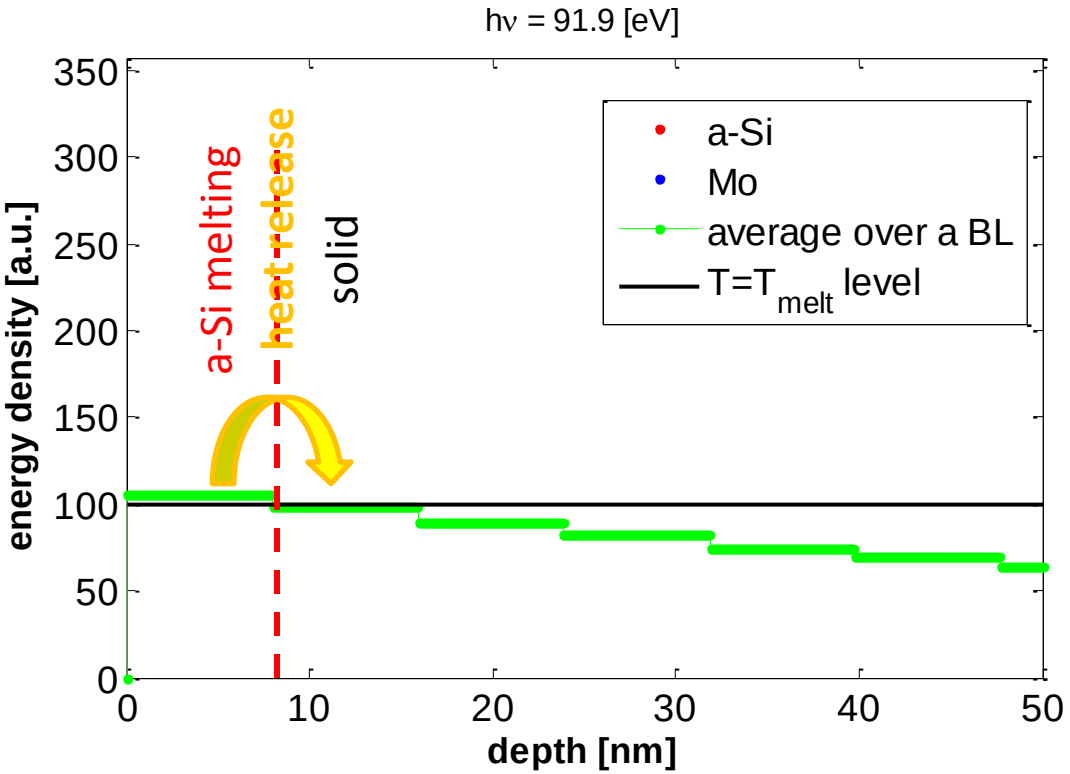
Atomic diffusion in multilayer Mo/Si coating (hv ~92eV)







Single shot damage in Mo/Si ML - model

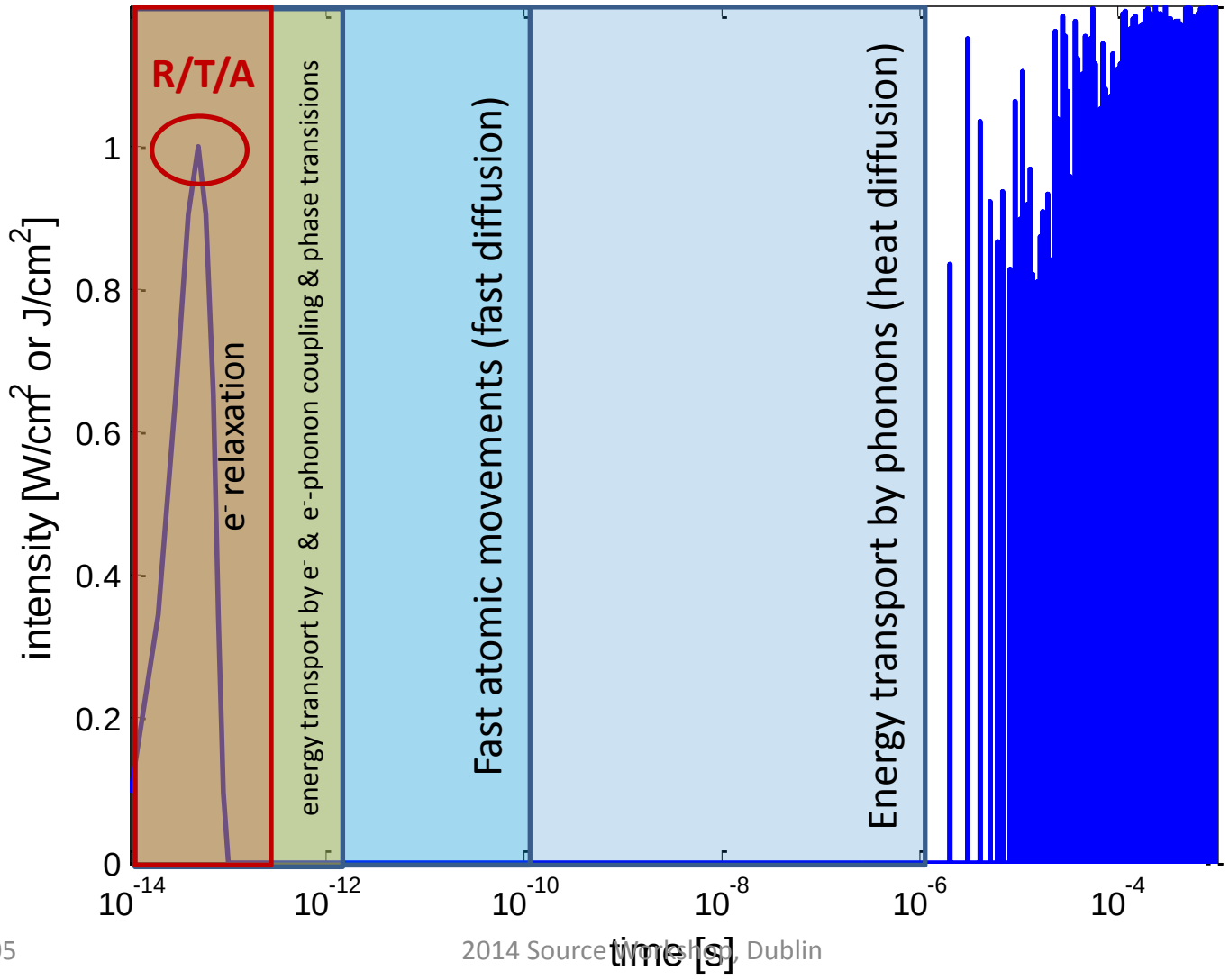


Damaging mechanism identified:

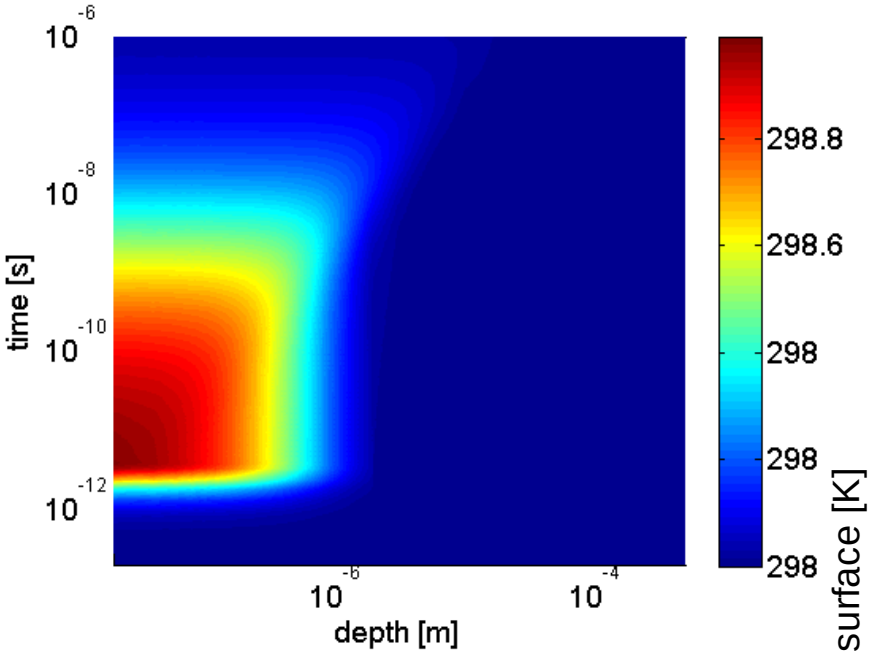
- *energy absorption*
- *energy diffusion transfers heat from Mo layers to a-Si*
- *melting of Si layers enables fast diffusion of Mo atoms into Si*
- *self-sustained reaction due to reaction heat release*
- *period compaction for bilayers with melted a-Si → crater formation*

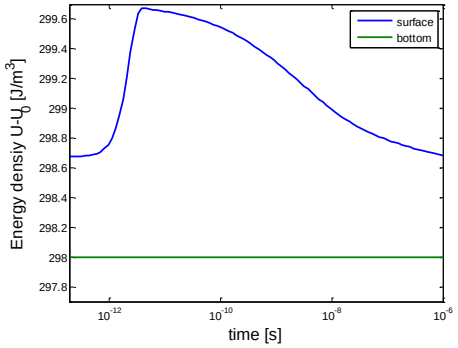
A.R. Khorsand, R. Sobierajski,et al.
Optics Express 18, s.700 (2010)

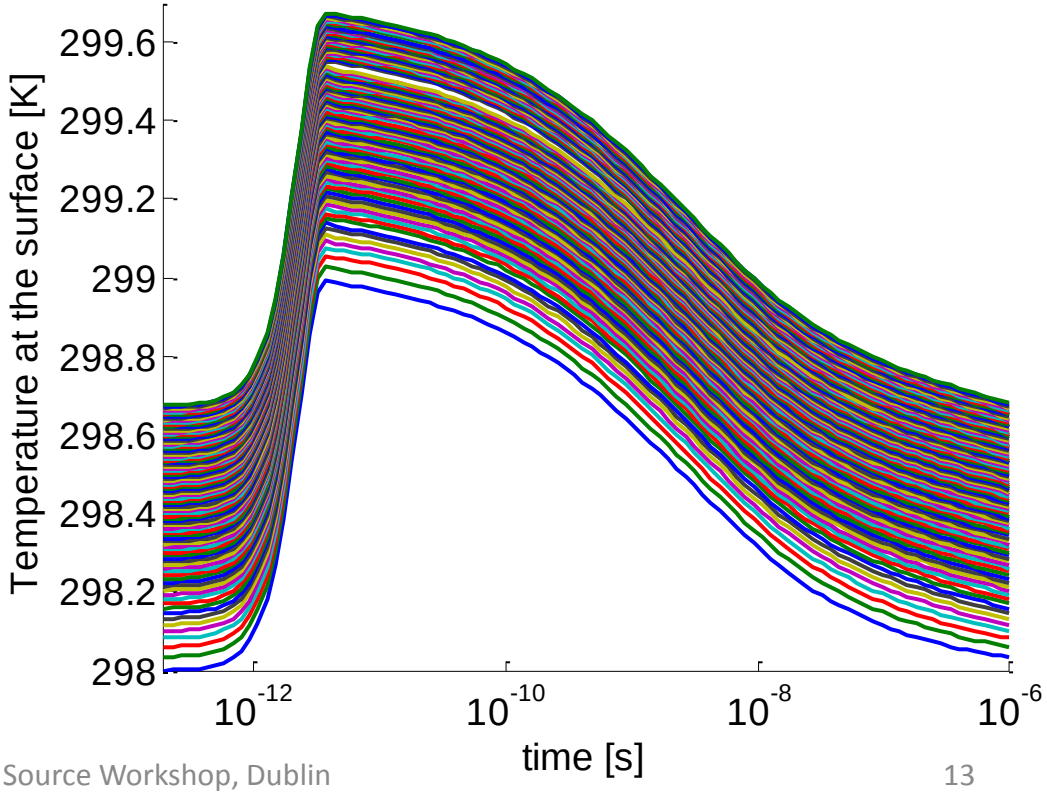
Characteristic times & processes



Heat diffusion by phonons & heat accumulation





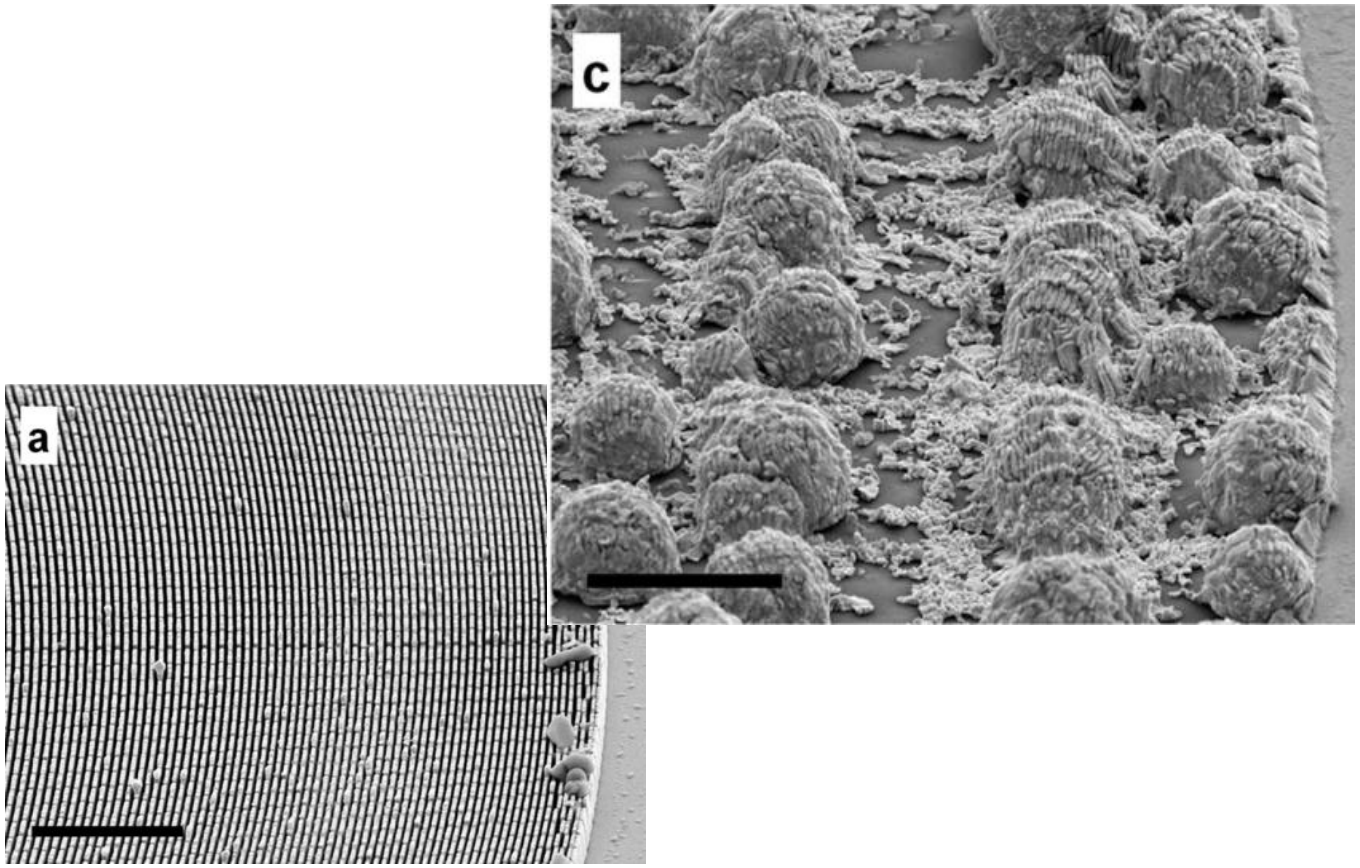


Si substrate
500 microns thick

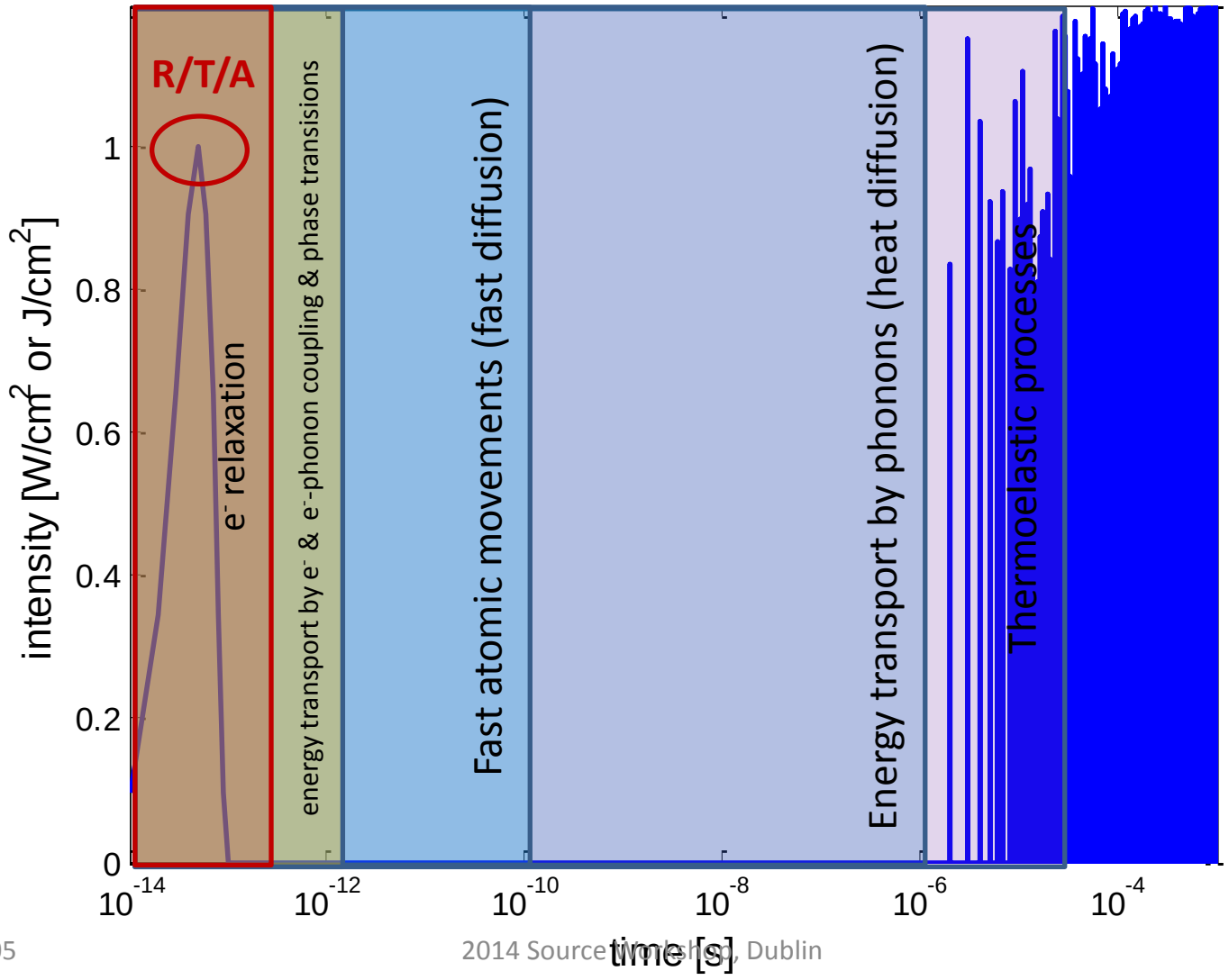
F~100 nJ/cm^2
λ=13.5 nm
normal incidence
L_{abs}~500 nm

Heat accumulation effects - melting

C. David et al. Scientific Reports Vol. **1**, (2011)



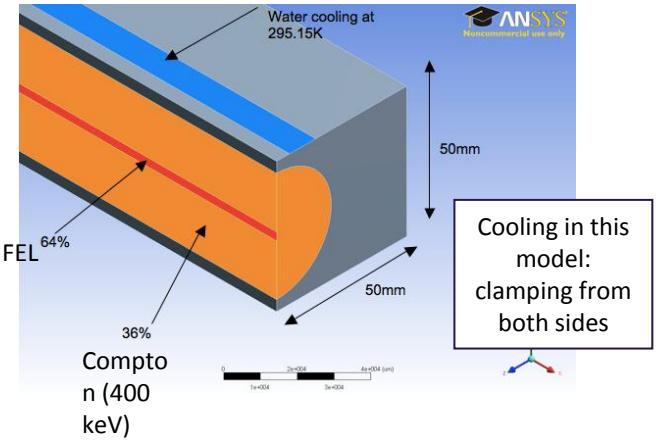
Characteristic times & processes

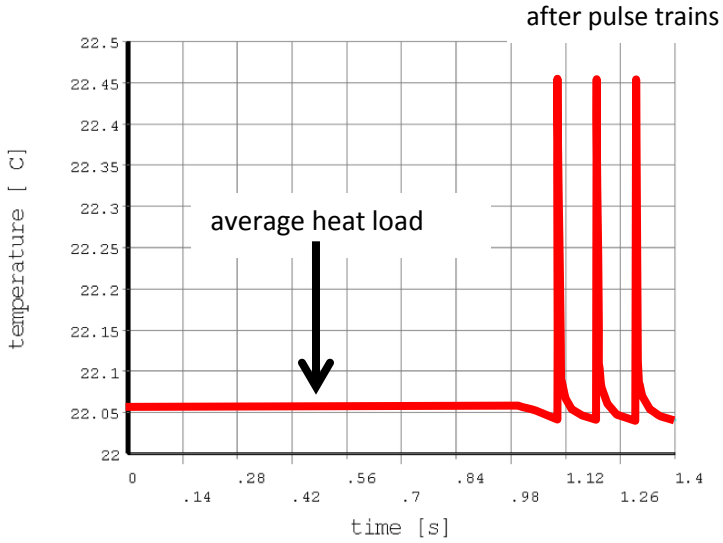


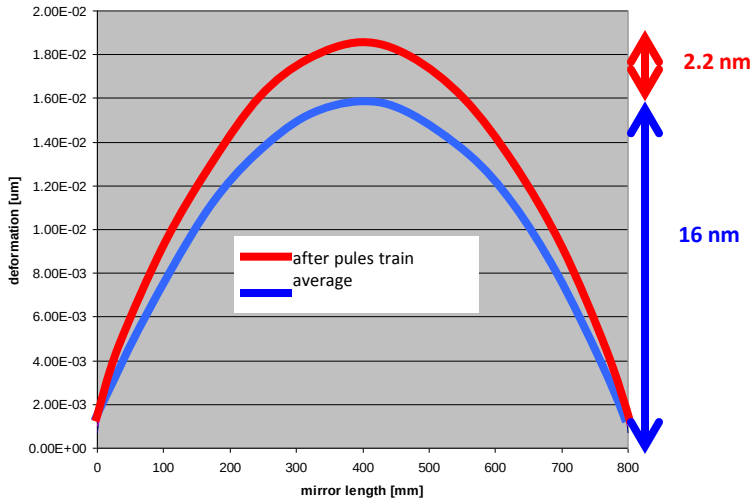
Heat load distribution on first mirror SASE1 @ Eu-XFEL

17.5 GeV,
13500 pulses per second

Slide courtesy H.Sinn
from X-ray optics CDR on xfel.eu (2011)







Time-resolved studies of the deformations

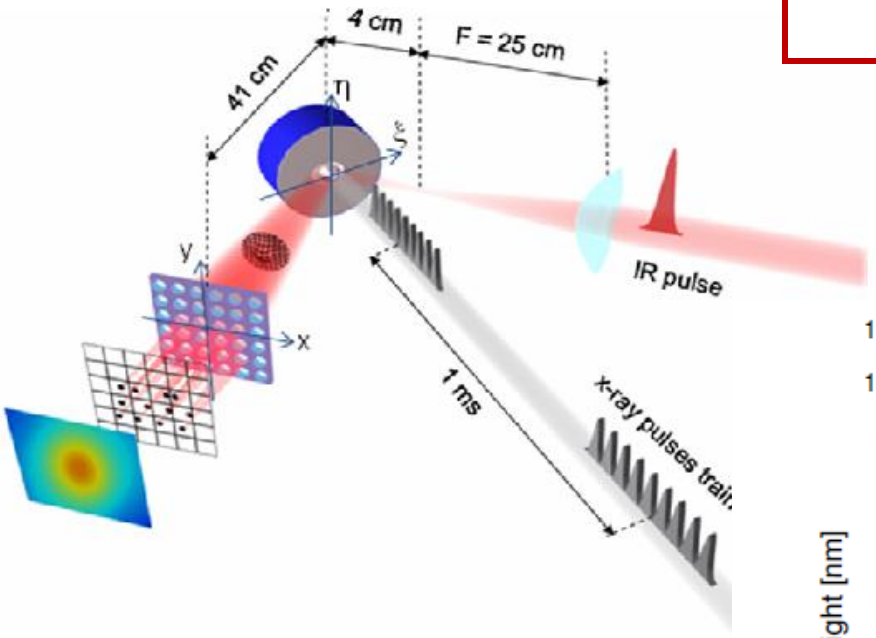
REVIEW OF SCIENTIFIC INSTRUMENTS VOLUME 74, NUMBER 8 AUGUST 2003

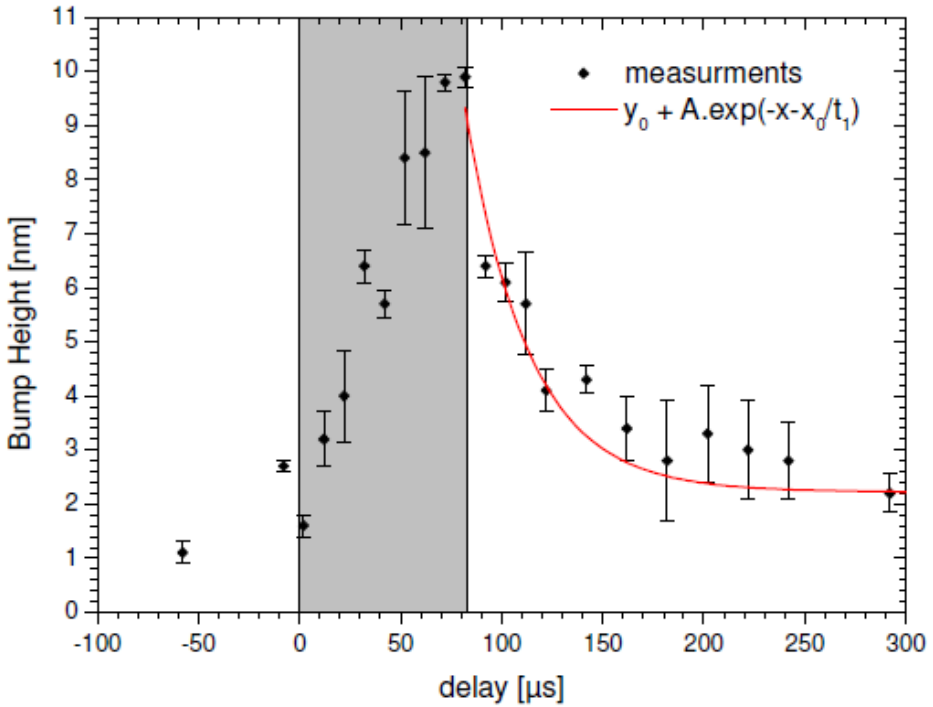
Thermal stresses in the reflective x-ray optics for the Linac Coherent Light Source

D. D. Ryutov[a)]
Lawrence Livermore National Laboratory, Livermore, California 945

(Received 21 January 2003; accepted 14 May 2003)

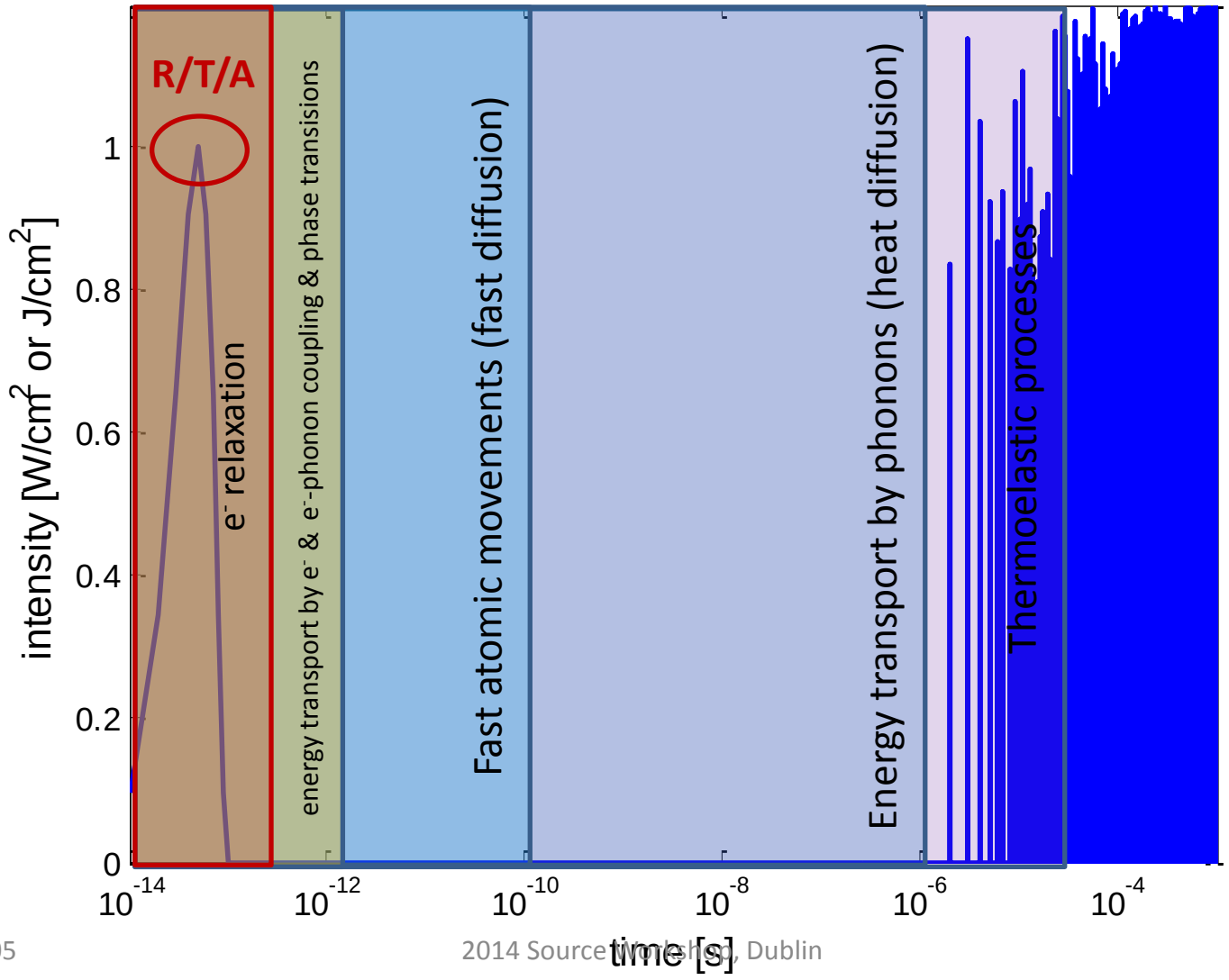
D.D.Ryutov
Rev. Sci. Instr. 74 (2003)





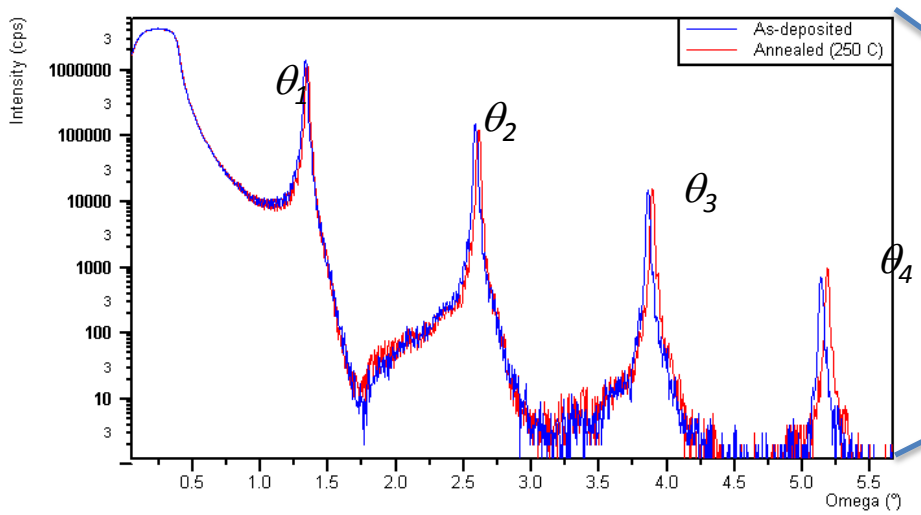
*J. Gaudin et al.,
Opt. Exp. 19 p.15516 (2011)

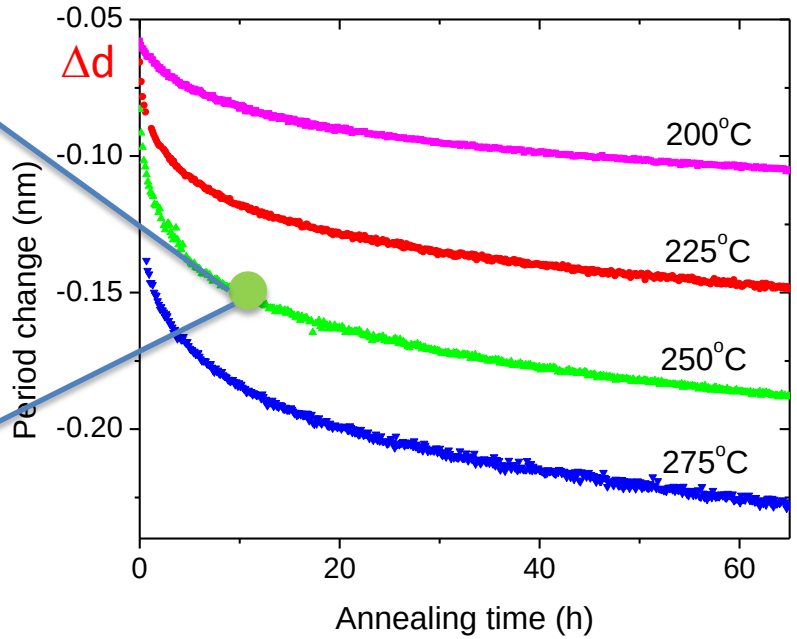
Beyond ms time scale



Atomic diffusion induced silicide formation

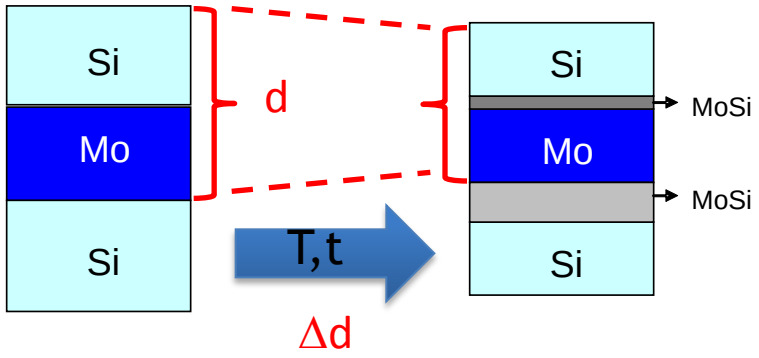
High res. Cu-K_a reflectance , 10h @ 250C



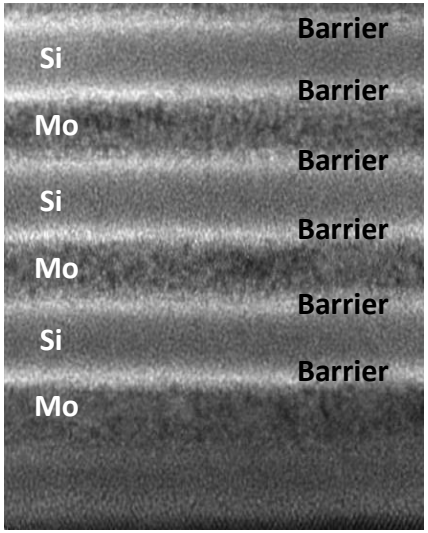


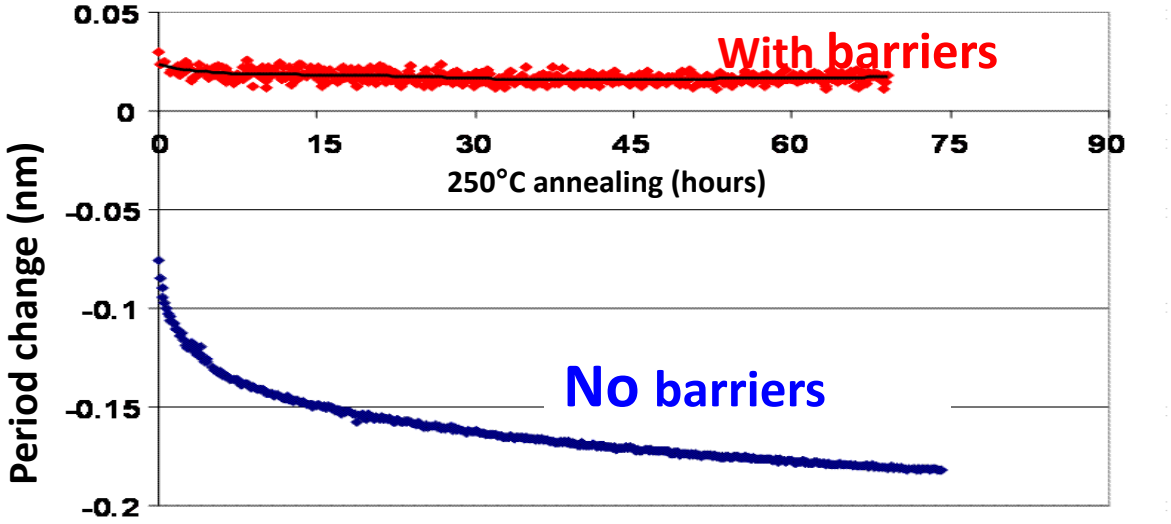
Bragg law: $$m\lambda = 2d\sin\theta_m\sqrt{1-\frac{2\bar{\delta}}{\sin^2\theta_m}}$$

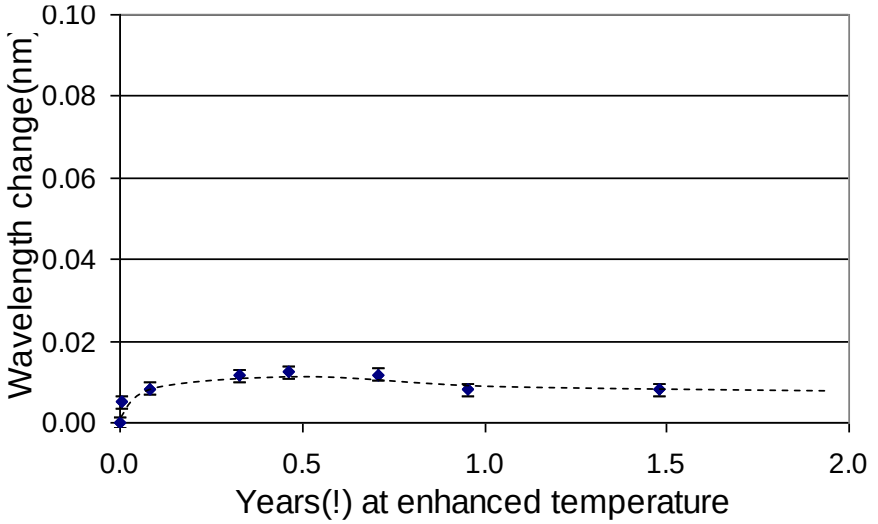
Growth of <u>high density</u> Mo_XSi_Y interfaces causes reduction of multilayer period



Thermally stable multilayer

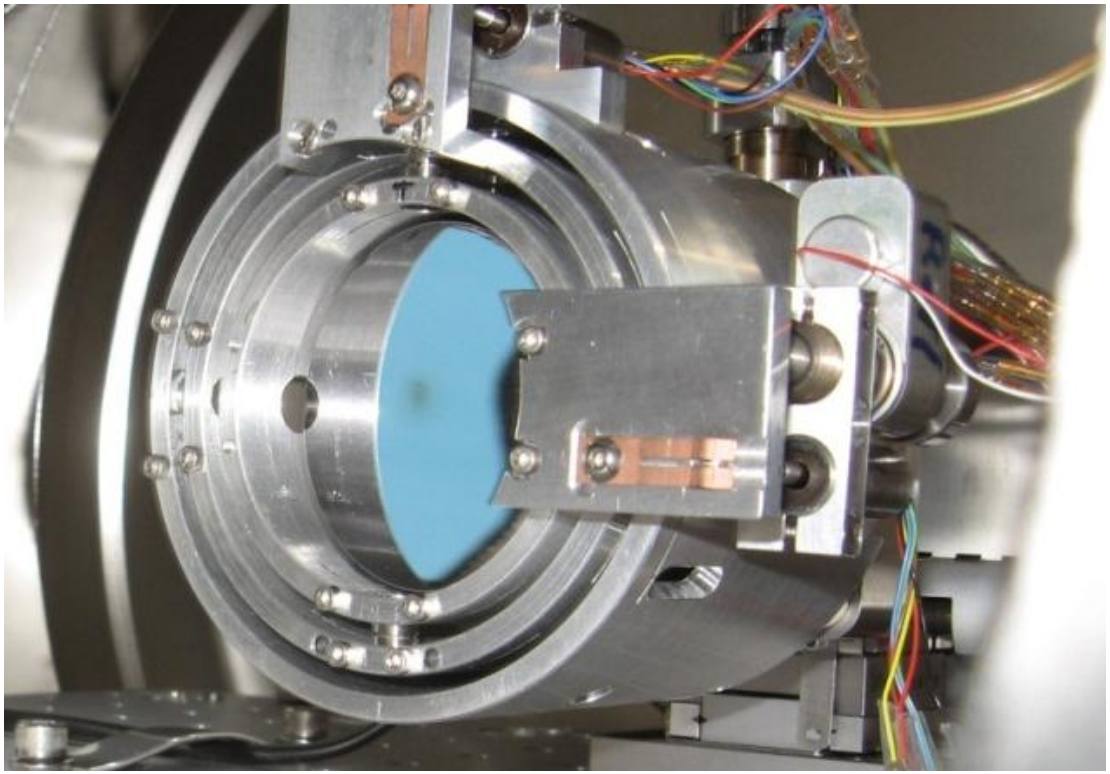






„Standard damage" processes

Surface contamination @ FLASH



IP PAS: R. Sobierajski, P. Dłużewski, M. Jurek, M. Klepka, D.Klinger, J.B. Pelka, W. Szuszkiewicz, D.Żymierska

WUT: D.Sobota, W. Wierzchowski, T. Płociński

IP ASCR: L. Juha, J. Chalupsky, V.Hajkova, T. Burian

HASYLAB: N. Stojanovic,

K. Tiedtke S. Toleikis H. Wabnitz

Uni. Essen: K. Sokolowski-Tinten,

LAC: J. Krzywinski, J. Bozek, M. Messerschmidt

LLNL: S. Hau-Riege, R. London

XFEL: J. Gaudin, H.Sinn

FOM: R.A. Loch, E. Louis, S. Bruijn, A.R. Khorsand, R.W. E. van de Kruijs,

SPRING-8: M.Yabashi, M.Nagasono

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